Effect of Anesthesia Type on Limb Length Discrepancy After Total Hip Arthroplasty

Sathappan S. Sathappan, MD, Daniel Ginat, MD, Vipul Patel, MD, Michael Walsh, PhD, William L. Jaffe, MD, and Paul E. Di Cesare, MD

Abstract: A retrospective study of 132 patients (63 spinal anesthesia and 69 general anesthesia) undergoing total hip arthroplasty was performed by 4 fellowship-trained adult reconstructive surgeons to determine the influence of anesthesia type on postoperative limb length and medial offset. Limb length discrepancy occurred in 87.0% of patients who received regional anesthesia as opposed to 47.6% patients who had general anesthesia (P < .001). Differences in postoperative medial offset measurements between the 2 groups were not statistically significant. It was concluded that surgeons operating on patients who receive regional anesthesia should supplement intraoperative tests for assessing hip stability with meticulous preoperative templating to avoid overlengthening the operative limb. Key words: total hip arthroplasty, limb length discrepancy, regional anesthesia, general anesthesia, preoperative templating.

Typical pathological features of hip degenerative joint disease are progressive loss of cartilage and superior migration of the femoral head, which result in a limb length discrepancy (LLD). This can lead to progressive structural changes in the lumbosacral spine [1] and is often associated with abnormal joint reaction forces [2]. Preexisting LLD should be accounted for during preoperative planning and should be corrected at the time of total hip arthroplasty (THA) [3].

A common complication of THA is postoperative LLD [4], which often manifests as lengthening of the operated limb [5-7]. Clinical sequelae from LLD include postoperative limp, low back pain, need for shoe lifts, hip instability, neurological effects (eg, paresthesia or weakness of the operated limb), and/or revision arthroplasty [5,8-13]. Limb length discrepancy after THA has been reported to occur in the range of 3 to 70 mm [4,5,9-11,13-20]. Older reports of LLD can be attributed to the absence of lateralized neck options, which necessitated increasing the vertical offset to improve overall hip stability [21-24]. Therefore, with the introduction of implant modularity, it had been predicted that there would be a decreased occurrence of postoperative LLD [25]. Limb length discrepancy, however, remains a common finding after THA and has also been associated with patient dissatisfaction [4] and medicolegal complaints [12,26-28].

Regional (eg, spinal or epidural) anesthesia, which is associated with fewer postoperative complications (eg, deep vein thrombosis) than general anesthesia, has become widely favored in THA [29-32]. Global soft tissue laxity produced by spinal anesthesia also facilitates surgical exposure [30,33]. A critical issue in the intraoperative setting of THA is assessment of soft tissue tension because this is typical among the tests performed to determine hip stability [34,35]. During assessment with trial hip components, surgeons may use soft tissue–related tests (shuck or dropkick test) [36] or subject the hip

From the Department of Orthopaedic Surgery, Musculoskeletal Research Center, NYU Hospital for Joint Diseases, New York, New York. Submitted February 13, 2006; accepted January 14, 2007. No benefits or funds were received in support of the study. Reprint requests: Paul E. Di Cesare, MD, Department of Orthopaedic Surgery, UC Davis Medical Center, 4860 Y St, Suite 3800, Sacramento CA 95817. © 2008 Elsevier Inc. All rights reserved.
to extreme arcs of motion to assess for instability. Satisfactory stability can be achieved by increasing the vertical and medial offset (neck length) [37]; however, this can also result in lengthening of the limb [27,38]. The purpose of this study was to determine whether lengthening of the operated limb and medial offset after THA are more likely using spinal or general anesthesia.

**Materials and Methods**

After institutional review board approval, 200 patients were randomly selected from the primary THA cases performed by 4 fellowship-trained senior adult reconstructive surgeons (surgeons 1-4 [S1-S4]) between 1997 and 2004. Patients were excluded if they required complex primary hip arthroplasty (eg, dysplastic hip, ankylosed hip, fractures about the hip, protrusio acetabuli, neuromuscular conditions, skeletal dysplasias, previous bony procedures about the hip [3]) or revision hip arthroplasty or had preexisting LLD not attributable to the hip. This selection process yielded 132 patients eligible for the study (Table 1).

Patient and surgical parameters (age, sex, diagnosis, date of surgery, operative techniques, and significant postoperative complaints) were recorded. Preoperative radiographic assessment of the hips consisted of anteroposterior and lateral radiographs taken non–weight bearing. When possible, anteroposterior radiographs were taken with the legs in 15° to 20° internal rotation so that the femoral head and neck were parallel to the radiographic cassette to facilitate templating and accurate measurements [39,40].

Although all surgeons performed preoperative templating to determine optimal implant sizes, only S1 and S3 used the templates/surgical techniques to specifically determine the femoral neck osteotomy level. Surgeon 1 sought to replicate the limb length and medial offset of the contralateral limb and used these parameters to guide the level of the osteotomy at an appropriate distance from the lesser trochanter [26,41]. Surgeon 1 was meticulous in templating and making intraoperative measurement from the level of the lesser trochanter to the center of the femoral head and correlating the level of the head to the top of the greater trochanter. Surgeon 1 did not rely on the shuck test to assess hip stability after the trial implants were in place, but tested the hip throughout the range of motion for stability. Surgeon 3, after using preoperative templating to determine an appropriate size for the trial stem, aligned the prosthetic head with a +5-mm neck length (leaving the option open to use a shorter or longer neck size if changes were necessary at the time of trial reduction) with the center of the native femoral head. Surgeons 2 and 4 used a standard 10-mm femoral neck calcar cut proximal to the top of the lesser trochanter and adjusted leg length with various head neck options.

The anesthesiologist determined choice of regional anesthesia (spinal in all cases) or general anesthesia. In general, patients in whom a spinal anesthesia had previously been unsuccessfully attempted as well as those who refused spinal anesthesia received general anesthesia. No patient who received general anesthesia had muscle paralysis at the time of trial reduction. A comparison of the 2 anesthesia groups is listed in Table 2. The mean age of patients was 57 years (range, 22-86); 61 were male and 71 female. There were 87 uncemented and 45 cemented femoral stems; all patients had uncemented cups. The preoperative diagnoses were osteoarthritis in 102, posttraumatic osteoarthritis in 10, inflammatory arthritis in 9, and avascular necrosis in 11. Mean body mass index (BMI) values of the 2 anesthesia groups were similar; however, patients receiving general anesthesia were significantly younger, significantly more of them were male, significantly more had a preoperative diagnosis of osteonecrosis, and significantly fewer had preoperative diagnoses of osteoarthritis or inflammatory arthritis.

The operative techniques used by the 4 surgeons were similar. All patients were placed on a lateral decubitus position and stabilized with the aid of a pelvic positioner; all procedures were performed through the posterolateral approach. In all cases, hip stability was assessed after the final acetabular

| Table 1. Patient Distribution in the 4 Study Cohorts |
|-----------|-----------|-----------|-----------|-----------|
|           | S1        | S2        | S3        | S4        |
| Spinal anesthesia | 16        | 11        | 22        | 16        |
| General anesthesia | 16        | 21        | 15        | 15        |

| Table 2. Characteristics of General and Spinal Anesthesiology Patients in the Study |
|-----------------------------------------------|--------|--------|-------|
| Confounder                                | General | Spinal | P |
| Diagnosis                                    |        |        | .002 |
| Osteoarthritis                              | 83.1%  | 93.7%  |     |
| Osteonecrosis                                | 14.1%  | 0      |     |
| Inflammatory arthritis                       | 3.0%   | 6.4%   |     |
| Sex (female)                                 | 50%    | 73.9%  | .005 |
| Mean age, y (SD)                             | 54.1 (14.9) | 62.0 (13.4) | .0009 |
| Mean BMI (SD)                                | 31.5 (8.4)  | 29.9 (5.9)  | .24  |
component and liner were implanted with the final femoral broach with trial head/neck components in place. During this stage, the surgeons used different techniques to optimize soft tissue tension and limb length. Surgeon 1 measured the distance between the center of the hip and the lesser trochanter and optimized the femoral head such that it approximated the preoperative template measurement. Surgeons 2 and 3 optimized hip stability by supplementing the neck according to the push-pull test (shuck test). Surgeon 4 measured the increase in distance between a defined trochanteric point and a Steinmann pin placed into the ischium at the infracotyloid groove of the acetabulum [7].

Immediate preoperative and outpatient postoperative anteroposterior radiographs taken at a mean of 6 weeks (range, 4-8 weeks) were reviewed by one of the research team who was blinded to the type of anesthesia and surgeon. The anatomical landmarks defined were the ischial tuberosities, apex (ie, most medial point) of the lesser trochanter, apex of the teardrop, and longitudinal axis of the femur. The teardrop was chosen as a standard reference instead of the ischial tuberosity because the teardrop has been described as a more consistent landmark [27,42]. The following parameters were documented from postoperative radiographs of both extremities:

1. **Vertical offset**: distance between transteardrop line and the medial apex of the lesser trochanter (Fig. 1A).
2. **Medial offset**: distance between the teardrop and the longitudinal axis of the femur (Fig. 1B). This is not the true **femoral offset** (which is defined as the perpendicular distance between the long axis of the femur and the center of rotation of the femur) [43].

To compensate for film magnification in the calculation of vertical and medial offsets, for each patient, the acetabular cup diameter on the radiograph was measured and compared with that of the actual cup. This step was important because of differences in magnification based on patient size, that is, less magnification in thin patients (14%), more in obese patients (26%) [44]. Based on these measurements, differences in vertical and medial offsets in the operated and contralateral limb were calculated after the differences in offsets from the presurgical and postsurgical radiographs were determined.

**Data Analysis**

Differences in the values of offset for the 2 anesthesia types were tested for statistical significance using a paired *t*-test. Postoperative LLD was divided into 4 main types:

- **Type I**: 0 to 5 mm
- **Type II**: >5 to 10 mm
- **Type III**: >10 to 15 mm
- **Type IV**: >15 mm

Differences in the occurrence of these LLD types between the spinal and general anesthesia groups were tested using Fisher exact test because of the low cell frequencies for some comparisons. Linear regression analysis was used to model the effect of

![Fig. 1. Documented parameters. A, Vertical offset—the distance between a horizontal line extending from the base of the teardrop and the medial apex of the lesser trochanter. B, Medial offset—the perpendicular distance from the base of the teardrop to the longitudinal axis of the femur. C, Schematic indicating relevant landmarks.](image-url)
anesthesia type on LLD, while controlling for potential confounding variables (age, BMI, sex, implant type, stem fixation).

The latest functional status of all patients was defined using Harris Hip Scores [45]. Charts were reviewed to determine whether patients had complained of significant LLD, had sought treatment for it, and/or had any related musculoskeletal complaints.

**Results**

Preoperatively, the affected limb in all patients was documented to be shorter than the contralateral limb by radiological and clinical evaluation. Postoperatively, mean differences in LLD (vertical offset) and medial offset between the operated and contralateral limb were measured (Table 3). Patients in the spinal anesthesia group (mean length = 9.87 mm, SD = 5.05 mm) experienced mean postoperative limb lengthening significantly greater than that in the general anesthesia group (mean = 2.6 mm, SD = 10.1 mm) (P < .05). There was no statistically significant difference in medial offset in hips performed using spinal (mean = 1.7 mm, SD = 10.1 mm) versus general anesthesia (0.4 mm, SD = 10.1 mm). Power analysis showed that our sample size was sufficient to detect a difference of 4.7 mm between the spinal and general anesthesia groups.

When patients were grouped according to anesthesia type using our postoperative LLD classification, it was found that 98.6% of patients who had general anesthesia were type I or II; in contrast, only 47.6% of patients in the spinal anesthesia group were type I or II (Table 4). Using the Fisher exact test, the difference between the 2 groups was found to be statistically significant (P < .001). Equalization of limb length (0.0 mm difference in vertical offset) was achieved in 14 patients in the general anesthesia group and only in 3 patients in the spinal anesthesia group. Potential confounders (age, BMI, sex, implant type, and fixation) were not significantly associated with differences in LLD.

Patients were followed up after THA for a mean period of 3.2 years (range, 1.2-6.7). Mean Harris Hip Scores improved from 58 points (range, 40-61) preoperatively to 97 points (range, 88-98) at the time of the latest follow-up. There were a total of 25 patients in categories III and IV and 1 patient in category II who perceived a difference in limb length. There were 4 patients (3%) in the general anesthesia group and 22 patients (17%) in the spinal anesthesia group who perceived a persistent difference. Among all patients with LLD, 10 complained of low back pain and 7 of pain in the contralateral hip. In the spinal anesthesia cohort, the perceived difference was large enough in 8 (36%) patients to require use of a shoe lift to counter symptoms attributable to LLD.

Three patients had hip dislocations: 2 patients (8 and 12 months after index THA) in the spinal anesthesia cohort and 1 patient (11 months after index THA) in the general anesthesia group. Dislocations were precipitated by abnormal flexion and internal rotation of the hip (as in getting out of a low-level bathtub) in all 3 cases; the numbers were too small for any further statistical analysis.

**Discussion**

One of the intraoperative challenges in THA is correcting limb length inequality without compromising hip stability [7,8]. After THA, if the operated limb is short, patients may not complain because they have been physiologically and psychologically accustomed to this condition [7]. A more common problem after THA, however, is lengthening [5-7].

<table>
<thead>
<tr>
<th>LLD Type</th>
<th>Spinal</th>
<th>General</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>15</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>II</td>
<td>15</td>
<td>8</td>
<td>23</td>
</tr>
<tr>
<td>III</td>
<td>27</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>IV</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>69</td>
<td>132</td>
</tr>
</tbody>
</table>

**Table 3. Mean Medial and Vertical Offset Difference in the Operative Limb (in millimeters [SD])**

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal</td>
<td>Medial offset</td>
<td>+2.8 (11.6)</td>
<td>+1.3 (10.2)</td>
<td>−1.8 (10.4)</td>
</tr>
<tr>
<td></td>
<td>Vertical offset</td>
<td>+4.6 (4.2)</td>
<td>+11.3 (3.2)</td>
<td>+12.7 (3.5)</td>
</tr>
<tr>
<td>General</td>
<td>Medial offset</td>
<td>−2.6 (8.5)</td>
<td>+6.1 (13.9)</td>
<td>+0.3 (6.6)</td>
</tr>
<tr>
<td></td>
<td>Vertical offset</td>
<td>+1.2 (0.9)</td>
<td>+4.4 (1.9)</td>
<td>+3.5 (3.4)</td>
</tr>
</tbody>
</table>

Negative values indicate reduced measurement on the operated side compared with the contralateral side.
Although one might expect modular femoral stem designs with high offset capabilities [43,46] to result in lower rates of LLD after THA, limb length inequality has been reported to affect as many as 18% of patients undergoing THA with these designs [33,47]. Edeen et al, who evaluated the clinical significance of leg length inequality in patients after THA [4], reported that radiographic assessment revealed a mean difference of 14.9 mm between the operated and contralateral limbs; as much as 32% of their patients were aware of and dissatisfied with this problem.

There has been a shift toward regional anesthesia (eg, spinal or epidural) as an alternative to general anesthesia in THA [30,32]. These modalities are typically associated with significant motor blockade [48], resulting in apparently abnormal and variable interpretation of intraoperative soft tissue tension tests, for example, shuck and dropkick tests. The shuck test involves applying axial traction to the lower limb distally; the extent of gapping in the hip joint serves as an indicator of soft tissue laxity [36]. The amount of gapping perceived at the joint line during these surgeon-initiated soft tissue tension tests is therefore influenced by the quantity of soft tissue releases, the applied axial forces, and, as evidenced from this study, the muscle relaxation from spinal anesthesia. There is a tendency to increase vertical offset and leg length to compensate for the perceived soft tissue laxity when regional anesthesia is used [8]. This increases the likelihood of a larger postoperative LLD in spinal anesthesia patients because they typically have greater soft tissue laxity intraoperatively. The current study, in which we radiographically evaluated the vertical and medial offsets in THA, found a statistically significant relationship between choice of anesthesia and occurrence of LLD. Among patients with type III or IV LLD, 74% were aware of the inequality and 8 (all from the spinal anesthesia group) resorted to using a shoe lift. Surgeon 2 often relied on the shuck test as a measure of hip stability; this resulted in a significant proportion of his THA patients with spinal anesthesia having type III and IV LLD. Patients of S1, who strictly used preoperative templating, and of S4, who used intraoperative quantification of limb lengthening, had less LLD than patients of both S2 and S3. Limitations of this study were that the 2 groups of patients were not equivalent in terms of diagnosis, sex, or age and that none of the hip radiographs was taken weight bearing. Although the 2 groups of patients differed as indicated, it is unlikely that these factors confounded the leg length assessment because these patients had surgery during the same period by an experienced total joint surgeon each using his specific technique for leg length assessment.

There is no consensus in the literature on what constitutes a “significant” LLD after THA [9,21]. Many authors recommend that the operated limb length should be within 10 mm of the contralateral limb because this does not affect the functional parameters of gait [49] and produces a satisfactory result in most patients [8,50]. In our study, we found that patients with a discrepancy of up to 10 mm (type I or II LLD) were generally satisfied with the outcome (80%).

A variety of methods are used to measure limb length, such as full-length hip-to-ankle radiographs, ultrasound techniques [51], and the more accurate computed tomographic scanograms [33,34]. We used a radiographic method similar to those used by other authors [8,52]. Although it is possible that measurements can be affected by the position of the hip and pelvic obliquity, patients with complex hip pathology were excluded from our study. All our patients were treated via a posterior surgical approach, and we did not include patients treated via an anterior or lateral approach for comparison. Although some studies have shown variations in dislocation rates associated with particular surgical approaches, none have reported any essential differences in LLD or overall postoperative outcomes [53-56].

The causes of limb lengthening after THA include functional lengthening (eg, pelvic obliquity) [6,26], component malpositioning (eg, inferior placement of acetabular cup) [9,16], and choice of anesthesia. We conclude that the use of spinal anesthesia for THA is associated with soft tissue laxity, which can increase the likelihood of excessive limb lengthening. When performing total hip arthroplasty under spinal anesthesia, the surgeon should not rely on the shuck test to assess hip stability but should test range of motion for stability. The meticulous use of templating and intraoperative measurements seems to be the best method of ensuring limb length equality among the 4 surgeons in this study. Thus, preoperative templating should supersede intraoperative soft tissue tension tests to ensure limb length equalization, especially when patients receive regional anesthesia.

Acknowledgments

The authors thank Joseph D Zuckerman, MD; Edward Adler, MD; Gregg Jarit, MD; Edward Su,
MD; R Damani Howell; and Michele Yoon for their assistance on this project.

References


